(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 583 038 A1**

(12) EUROPEAN PATENT APPLICATION

(21) Application number : **93202345.0**

(22) Date of filing : **09.08.93**

(51) Int. Cl.[5] : **H02M 3/335**

(30) Priority : **10.08.92 NL 9201428**

(43) Date of publication of application : **16.02.94 Bulletin 94/07**

(84) Designated Contracting States : **DE ES FR GB IT NL**

(71) Applicant : **PHILIPS ELECTRONICS N.V.**
Groenewoudseweg 1
NL-5621 BA Eindhoven (NL)

(72) Inventor : **Marinus, Antonius Adrianus Maria**
c/o Int. Octrooibureau B.V., Prof. Holstlaan 6
NL-5656 AA Eindhoven (NL)

(74) Representative : **Kooiman, Josephus Johannes Antonius et al**
INTERNATIONAAL OCTROOIBUREAU B.V.
Prof. Holstlaan 6
NL-5656 AA Eindhoven (NL)

(54) Power supply circuit and control circuit for use in a power supply circuit.

(57) A power supply circuit for generating a stabilized power supply generally comprises a series arrangement of a primary winding (7) of a transformer (T) and a switch (9). The switch is controlled by means of a control circuit (21), an input of which receives a signal (Vf_b) related to the output voltage of the power supply circuit. The control circuit (21) determines the duty cycle of the switch (9). Dependent on the power consumption of the load (R_b) connected to the output of the power supply circuit, the duty cycle is either increased or decreased. The duty cycle has a given minimum value which is caused by the inertia of the switch (9) upon switching on and switching off. The minimum duty cycle may be reached, *inter alia,* when the power supply circuit works in an apparatus using a standby mode.

With reference to the power to be supplied to the load and/or with reference to the duty cycle, the power supply circuit according to the invention determines the moment when the frequency of the control signal to be generated by the control circuit is switched to another fixed frequency.

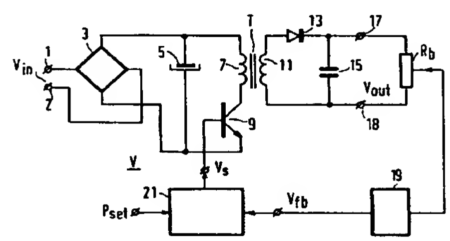


FIG.1

EP 0 583 038 A1

FA

The invention relates to a power supply circuit having input terminals for receiving an input voltage and output terminals for supplying an output voltage, which circuit comprises, coupled parallel to the input terminals of the power supply circuit, a series arrangement of a primary winding of a transformer and a switch, a secondary winding of the transformer coupled to the output terminals of the power supply circuit and a control circuit having an input which is coupled to the output terminals of the power supply circuit and an output for applying a control signal to the switch, said control circuit comprising an oscillator circuit for generating a pulse width-modulated control signal having a predetermined frequency.

The invention also relates to a control circuit for use in such a power supply circuit.

A power supply circuit of this type is known from German Patent Specification DE-C-3444035.

To ensure that an output voltage does not change independently of load variations, pulse width modulation (PWM), also referred to as duty cycle control, is generally used. A drawback of pulse width modulation (duty cycle control) is that the width of the pulse has a minimum. If the load decreases, the width of the pulse is reduced so as to keep the output voltage equal. Since the pulse is applied to a control electrode of, for example a transistor operating as a switch, it will take some time at the moment of the start of the pulse before the switch is rendered conducting. Moreover, at the end of the pulse it will take some time before the switch becomes non-conducting. At a given pulse width the switch will be conducting for a given minimum period of time and a further reduction of the pulse width does not have any influence on the conductivity time of the switch, until the width of the pulse becomes so narrow that the switch is not rendered conducting at all anymore.

Apparatuses such as television receivers, *etc.* in particular are in a standby mode for the greater part of the time. During this time only a small part of the apparatus is power supplied, *inter alia,* for example the reception section of the remote control unit. A general object is to ensure that the apparatuses in the standby mode consume a minimum quantity of energy. Due to this object, the width of the pulse in the standby mode becomes increasingly narrower when using pulse width modulation, so that the above-mentioned problems arise, or even get worse. Also in applications in which a (mains-supplied) apparatus requires a small quantity of power during a given part of the time (which need not be the above-mentioned standby mode) the above-mentioned problems occur. This problem is solved in the above-mentioned German Patent Specification by switching over from pulse width modulation to pulse packet control after the load has been detected to be below a given value. The pulse packet control implies that a plurality of pulses is successively applied at equal intervals and at a fixed width (wider than the minimum width) to the switch, whereafter no pulses are generated for a given period of time. The number of pulses is dependent on the load. A drawback of the known control is that the voltage generated by means of the switch and a conventional (primary winding of a) transformer (or wire-wound coil) should be extensively filtered to make the voltage suitable to be applied to a load, which filtering is necessary because the generated voltage has a large variation (ripple).

A further drawback of this known control is that audible transformer noise occurs. This is a vibration of the core (caused, *inter alia* by the air gap) and of the wires of the windings of the transformer, which vibration occurs in the transformer due to a low-frequency varying magnetic field.

It is, *inter alia,* an object of the invention to provide a power supply circuit and a control circuit which do not have the above-mentioned drawbacks. To this end, a power supply circuit according to the invention is characterized in that the control circuit is adapted to receive a feedback signal at the input of the power to be supplied at the output terminals of the power supply circuit and is adapted to receive at a further input a signal to be externally set, said control circuit also comprising switching means for switching an oscillator of the oscillator circuit from the predetermined frequency to another fixed frequency in dependence upon the signal to be externally set and the feedback signal.

Switching the frequency when detecting that the load connected to the power supply circuit requires a power which is below the externally set value has the advantage that the duty cycle of the switch maintains such a value that this duty cycle remains above the minimum value. Moreover, due to the frequency switching, the power supply circuit operates more effectively because the losses in the different elements of the power supply circuit relatively become increasingly larger when the power required by the load is supplied, hence at a smaller duty cycle. By switching the frequency, the switch is switched on for longer periods of time in succession, but at a lower frequency.

The two frequencies of the oscillator circuit may differ, for example by a factor of two.

An embodiment of a power supply circuit according to the invention is characterized in that the control circuit comprises means for detecting the moment of switching to the other fixed frequency with reference to a current flowing through the switch during operation.

During operation a sawtooth-shaped current flows the series arrangement of the primary winding of the transformer and the switch. The less power the load requires, the smaller the peak value of the current flowing through the switch. Consequently, this is a measure of determining the moment of switching

the frequency.

A further embodiment of a power supply circuit according to the invention is characterized in that the means comprise a differential amplifier for amplifying the difference between the feedback signal and a reference signal, an output of the differential amplifier being coupled to the switching means.

Another embodiment of a power supply circuit according to the invention is characterized in that the control circuit comprises means for detecting the moment of switching to the other fixed frequency with reference to the given duty cycle, said means comprising an extra winding on the transformer, and a duty cycle detection circuit for detecting the duty cycle and for supplying a switching signal to the oscillator circuit.

The control circuit may be an integrated circuit and can also be used in other power supply circuits.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter. In the drawings

Fig. 1 is a general circuit diagram of a power supply circuit,

Fig. 2 shows a first embodiment of a control circuit for use in the power supply circuit according to the invention, and

Fig. 3 shows a second embodiment of a control circuit for use in a power supply circuit according to the invention.

Fig. 1 shows a power supply circuit V which receives an input alternating voltage Vin (for example, the mains voltage) at input terminals 1 and 2. The input terminals are connected to a rectifier 3 for full-wave rectification of the input alternating voltage. A buffer capacitor 5 is connected across outputs of the rectifier. A series arrangement of a primary winding 7 of a transformer T and a transistor 9 operating as a switch is arranged parallel to this capacitor (in this embodiment the transistor is an NPN transistor, but a FET is alternatively possible; the choice of the type of transistor/switch is determined by specific design requirements and is known to those skilled in the art).

A secondary winding 11 of the transformer is connected to a series arrangement of a diode 13 and a capacitor 15. Output terminals 17 and 18 of the power supply circuit V supply an output voltage Vout across the capacitor 15. A load Rb (shown as a resistor) is connected across the output terminals. This load may be, for example all kinds of components of a display device, radio, CD player but also, for example a lamp.

The power supply circuit V further comprises a detection circuit 19 for detecting the energy to be supplied by the power supply circuit. The detection circuit supplies a signal Vfb to a control circuit 21 which, dependent on the load determined by the detection circuit (the power required), controls the period of conductance of the transistor 9. The detection circuit may comprise, for example a differential amplifier and an opto-coupler for maintaining a DC separation between the load (Rb) and the input side of the power supply circuit. The control circuit 21 also has a second input for receiving a predetermined minimum power Pset (the control circuit 21 will be further described with reference to Figs. 2 and 3).

As stated above, such a power supply circuit is used, for example in a display device. The majority of present-day display devices uses a standby mode, in which mode the display device is switched off and can be switched on by means of, for example a remote control unit. During this standby mode the load is much lower than during normal use (during the standby mode, *inter alia* the display tube is not provided with the high voltage required for display). During the standby mode the control circuit 21 will therefore control the transistor (switch 9) with a much smaller duty cycle (a lower load requires less power).

When the load decreases, the width of the pulse is reduced so as to keep the output voltage equal. Since the pulse is applied to a control electrode of, for example a transistor operating as a switch, it will take some time at the moment when the pulse starts before the switch is rendered conducting (which is caused by the inertia of the transistor). At the end of the pulse it will also take some time before the switch becomes non-conducting. At a given pulse width the switch will be conducting for a given minimum period of time and a further reduction of the pulse width does not have any influence on the conductivity time of the switch, until the width of the pulse becomes so narrow that the switch does not become conducting at all anymore.

Apparatuses such as television receivers, *etc.* in particular are in a standby mode for the greater part of the time. During this time only a small part of the apparatus is power supplied, *inter alia,* for example the reception section of the remote control unit. A general object is to ensure that the apparatuses in the standby mode consume a minimum quantity of energy. Due to this object, the width of the pulse in the standby mode becomes increasingly narrower when using pulse width modulation, so that the above-mentioned problems arise, or even get worse.

A second problem which occurs when the load is derived (for example, during the standby mode) is that the power supply circuit becomes less effective at low loads. This implies that a relatively larger quantity of power is lost (is dissipated in the different elements of the power supply circuit) so that, relatively, an increasingly smaller quantity of power is available for the load.

Fig. 2a shows a first embodiment of the control circuit 21.

The control circuit receives the signal Vfb from the detection circuit 19 and applies this signal to a first input of a differential amplifier 23. The differential amplifier receives a reference voltage Vref at a sec-

ond input. This reference voltage is a voltage across the outputs 17, 18 (see Fig. 1) of the power supply circuit V (or a part thereof if Vfb *via*, for example a resistance division is also a part of the output voltage). The differential amplifier supplies the amplified difference as a voltage Ver at an output. The voltage Ver is applied to an input of a comparator 25. A second input of the comparator receives a signal Is which is a measure of the current flowing through the switch 9' (shown in this example as a FET) (measured across a measuring resistor Rm).

An output of the comparator 25 is connected to a reset input R of a flip-flop 27. The flip-flop receives a signal Vosc at a set input S, which signal originates from an oscillator circuit 29. Fig. 2c shows the different signals with respect to time. At instant t0 the signal Vosc has a (digital) high value. As a result, an output Q of the flip-flop 27 becomes digitally high, hence the output Q' (NOT-Q) becomes low. The output Q' of the flip-flop is connected to an inverting amplifier 31, which amplifier controls the switch 9' *via* an output resistor 33 having a voltage Vout. The current through the switch and through the measuring resistor Rm increases with a sawtooth shape. This results in a sawtooth-shaped signal Is at the second input of the comparator 25. The voltage Ver has a given DC value. At the instant (instant t1 in Fig. 2c) when the signal Is reaches this value, the value of the output of the comparator changes and supplies a reset signal (R, see Fig. 2c) to the flip-flop. Consequently, the output Q of the flip-flop becomes low and the output Q' becomes high so that the output signal Vout of the control circuit 21 becomes low. At instant t2 this cycle starts from the beginning again.

In this embodiment the control circuit also comprises a standby circuit 35 which receives the signal Ver at a first input. The standby circuit receives a signal Pset at a second input, which signal determines at which power consumption of the load the oscillator circuit 29 must switch. If the power consumption of the load decreases, the output signal Ver of the differential amplifier 23 also decreases. The standby circuit 35 determines with reference to the signal Ver (which is thus a measure of the power consumption) and with reference to the signal Pset when the frequency of the oscillator circuit 29 must be switched. The frequency of the oscillator is thus switched at a given minimum power (Pset). The power consumption is determined with reference to the signal Ver (which corresponds to a minimum peak current through the switch). At a decreasing power the frequency of the oscillator circuit is reduced so as to ensure that the switch (9, 9') is uninterruptedly on for a longer time (but at a lower repetition frequency) and to ensure that the power supply circuit is used more effectively. In Fig. 2c the graph for the current Is with Ver-stby shows the value of the output of the differential amplifier 23 at a low power consumption (for example during standby).

In Fig. 2b the power P and the switching point Pset are plotted on the vertical axis and the current I is plotted horizontally, while Fh denotes the high frequency and Fl denotes the low frequency (for example Fh = 2*Fl). Arrows show the variation at a decreasing power consumption of the load. At an increasing power consumption the graph (Fig. 2b) is traversed in the opposite direction. The term standby circuit 35 raises the presumption that the apparatus in which this power supply circuit/control circuit is used has a standby mode. However, whether the apparatus has a standby mode is not important for the invention and for this power supply circuit.

Fig. 3a shows a second embodiment of a control circuit 21 for use in a power supply circuit V (see Fig. 1). Elements having the same reference numerals as in Fig. 1 and/or 2 operate in a similar way.

Also in this embodiment the control circuit receives the signal Vfb from the detection circuit 19 (see Fig. 1). The signal Vfb is applied to an input of the differential amplifier 23 which receives the reference signal Vref at a second input again. The differential amplifier again supplies the signal Ver to an input of the comparator 25. The comparator receives the signal Is again at a second input (which is measure of the current through the switch 9'). The output signal of the comparator again serves as a reset signal R for the flip-flop 27. The output signal Vosc of the oscillator circuit 29 again serves as a set signal S for the flip-flop. Now the flip-flop also supplies the signal Q' (NOT-Q) to the inverting amplifier 31 whose output again supplies the output signal Vout as a control signal to the switch *via* the output resistor 33.

In order to determine when the frequency of the oscillator of the oscillator circuit 29 must be switched, an extra winding 37 on the transformer T is used instead of the signal Ver. This extra winding is connected to a duty cycle detection circuit 39 for determining the duty cycle of the switch 9' and for determining the switching moment of the oscillator circuit 29 with reference to the signal Pset. The duty cycle detection circuit determines the switching moment with reference to the duty cycle and the input signal Pset. This is shown diagrammatically in Fig. 3b. At a decreasing power (in the direction of the arrows) the duty cycle D reaches the value Dmin at a given moment, which value corresponds to a power consumption of Pset of the load. The duty cycle detection circuit 39 then supplies a signal to the oscillator circuit 29 whereupon the frequency of Fh is decreased to Fl (for example halved). In the case of an increasing power consumption of the load, the circuit of Fig. 3b is traversed in the opposite direction.

Claims

1. A power supply circuit (V) having input terminals (1, 2) for receiving an input voltage (Vin) and output terminals (17, 18) for supplying an output voltage (Vout), which circuit comprises, coupled parallel to the input terminals of the power supply circuit, a series arrangement of a primary winding (7) of a transformer (T) and a switch (9, 9'), a secondary winding (11) of the transformer coupled to the output terminals of the power supply circuit and a control circuit (21) having an input which is coupled to the output terminals of the power supply circuit and an output for supplying a control signal to the switch, said control circuit comprising an oscillator circuit (29) for generating a pulse width-modulated control signal having a predetermined frequency, characterized in that the control circuit is adapted to receive a feedback signal (Vfb) at the input of the power to be supplied at the output terminals of the power supply circuit and is adapted to receive at a further input a signal (Pset) to be externally set, said control circuit also comprising switching means (35) for switching an oscillator of the oscillator circuit from the predetermined frequency to another fixed frequency in dependence upon the signal to be externally set and the feedback signal.

2. A power supply circuit as claimed in Claim 1, characterized in that the control circuit comprises means for detecting the moment of switching to the other fixed frequency with reference to a current flowing through the switch during operation.

3. A power supply circuit as claimed in Claim 1, characterized in that the means comprise a differential amplifier for amplifying the difference between the feedback signal and a reference signal, an output of the differential amplifier being coupled to the switching means.

4. A power supply circuit as claimed in Claim 1, characterized in that the control circuit comprises means for detecting the moment of switching to the other fixed frequency with reference to the given duty cycle.

5. A power supply circuit as claimed in Claim 4, characterized in that the means comprise an extra winding on the transformer, and a duty cycle detection circuit for detecting the duty cycle and for supplying a switching signal to the oscillator circuit.

6. A control circuit for use in a power supply circuit as claimed in any one of the preceding Claims.

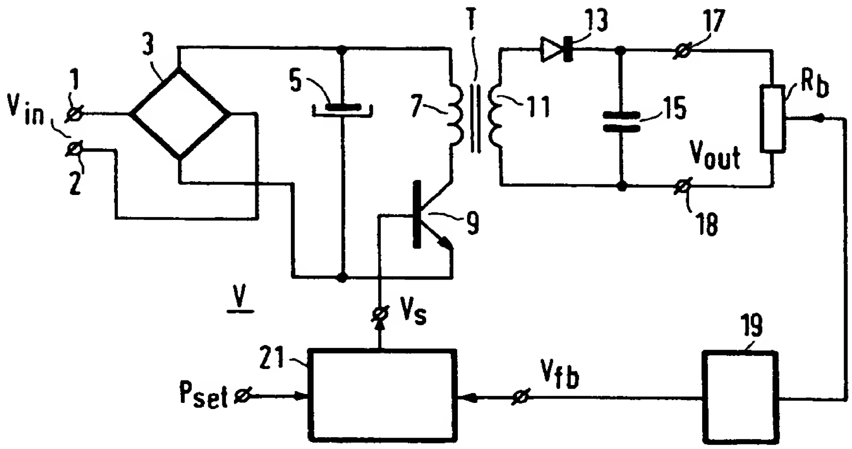

3
1
Vin
2
5
7
T
11
13
15
17
18
Rb
Vout
9
V
Vs
19
21
Pset
Vfb

FIG.1

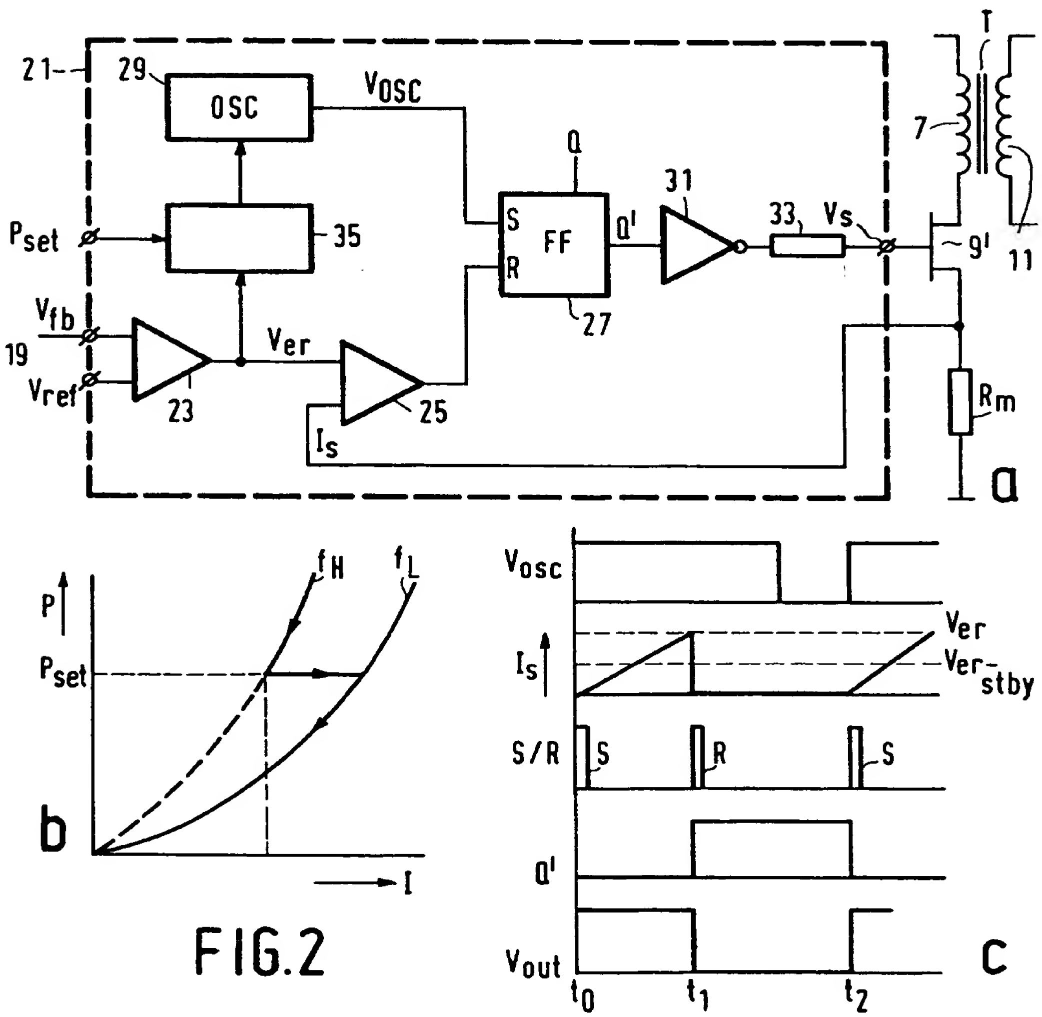
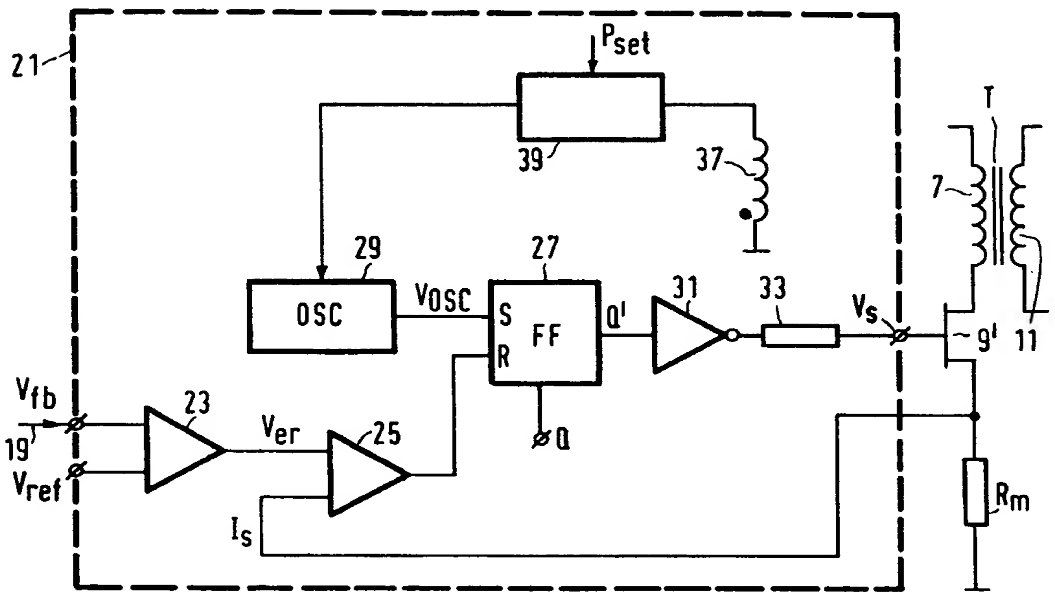
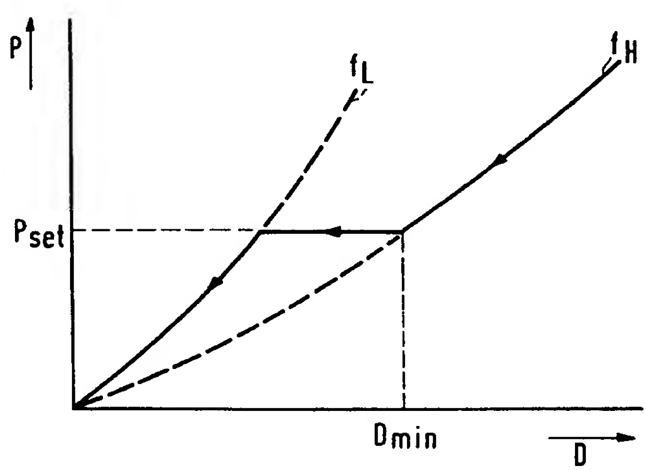

21
29
OSC
Vosc
Q
31
33
Vs
T
7
11
9'
Pset
35
S
R
FF
Q'
27
Vfb
19
Vref
23
Ver
25
Is
Rm
a
P
Pset
fH
fL
I
b
Vosc
Is
Ver
Ver-stby
S/R
S
R
S
Q'
Vout
t0
t1
t2
c

FIG.2


21
Pset
39
37
29
27
OSC
VOSC
S
R
FF
Q'
31
33
Vs
T
7
9'
11
Vfb
19
Vref
23
Ver
25
Q
Is
Rm

a


P
fL
fH
Pset
Dmin
D

b

FIG.3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 93 20 2345

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	WO-A-8 704 885 (DEUTSCHE THOMSON-BRANDT GMBH) 13 August 1987	1,6	H02M3/335
Y	* the whole document *	4	
Y	US-A-4 772 995 (GAUTHERIN ET AL.) 20 September 1988 * column 3, line 62 - column 4, line 24; figure 1 *	4	
A	EP-A-0 244 623 (MOTOROLA INC) 11 November 1987	1-3	
A	PATENT ABSTRACTS OF JAPAN vol. 5, no. 15 (E-43)29 January 1981 & JP-A-55 141 973 (SHINDENGEN ELECTRIC MFG CO) 6 November 1980 * abstract *	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

H02M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	01 OCTOBER 1993	BOURBON R.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document